PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Process for the Treatment of Liquids containing Suspended Particles with Sound and Ultra-sound Waves

We, Dr. EGON HIEDEMANN, of Trajanstrasse 18, Köln, Germany, and Dr. OTTO BRANDT, of Fürstenstrasse, 34, Köln-Mülheim, Germany, both German citizens, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

It has already been proposed to treat emulsions and the like with sound waves for the purpose of improving the dispersion. Such proposals have employed relatively short treatment chambers or have made use of cavitation obtained close to a small intensely vibrating generator past which the emulsion is led in a path which doubles back on itself at the generator.

The present invention relates to the treatment of melts and liquids of all kinds which contain suspended particles by the action of sound and ultra-sound waves for a quite opposite purpose to the prior proposals. Thus in disperse systems (colloids, suspensions) the present treatment can consist in the removal of suspended particles by acoustic flocculation (coagulation) or in a demixing of the disperse medium into turbid and clarified liquids. At the same time both actions can supplement one another. Among such disperse systems are also to be counted oils (lubricating and fuel oils) containing highly polymerised molecules which are to be regarded in a broad sense as suspended substances and make themselves noticeable by undesirable tenacity or by resinification. Such oils can be refined by acoustic and ultra-acoustic influence. The disperse system to which the invention applies also include emulsions i.e. dispersions of non-miscible liquids one in another. The invention requires that the vibrations shall be transmitted in a regular fashion over a length of liquid which is a multiple of its diameter. It also requires that cavitation shall be avoided or reduced to negligible proportions compared with the coagulating effect of the vibrations but as cavitation needs a very powerful generator and even then only occurs close to the sound generator, the long path necessary at the same time avoids difficulty through cavitation. It should here be noted that cavitation represents a failure of the liquid to vibrate with the generator, whereas the invention requires vibration of the liquid. According to the invention the desired result is obtained by transmitting through an elongated body of the liquid to be treated, over the whole or substantially the whole of its cross section, sound waves of a frequency of about 8 to 100 KH_z, the wave normal of which lies in or substantially in the longitudinal direction of the body of liquid, the length of the body being a multiple of its cross section so that any cavitation which may occur near the actual vibration generator does not hinder the coagulating effect of the vibrations. The minimum ratio of length to diameter is not critical and will vary according to the circumstances of any particular case but in general a ratio of three or four is the minimum.

Detailed experiments on the separation phenomena have shown that the effect achieved depends in great measure on the length of time T and the sound intensity I of the sound action, and that the action achieved increases at a rate greater than linearly with I being in part proportional to I^2 or still higher powers of I. From this fact it follows that the separation can be effected particularly economically if relatively small quantities of the substance to be treated are excited into intense vibration. This can only be done practically however if the process is carried out in a relatively small reaction chamber of the above specified proportions in which a high sound intensity can be achieved.

In carrying out the invention it is proposed therefore to excite the medium to be treated in a tubular separating chamber into intense short wave sound vibrations, the arrangement of the sound source being such that the wave normal falls in the direction of the longitudinal axis of the chamber. By this measure, first the disadvantage is avoided of the sound energy being dissipated as is the case with large

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reaction chambers. Apart from this the sound energy falls off very rapidly with the distance from the sound source so that excessively large sound sources would be necessary in large chambers. Finally in such chambers very confused and unsupervisable conditions arise through reflections. These disadvantages are avoided with the tubular reaction chamber, the diameter of which is advantageously not substantially greater than the radiating end surface of the sound generator.

In further development of the process according to the invention, the tubular separating chamber is tuned to resonance with the sound vibrations impressed on the medium. This acoustic resonance enables a maximum sound intensity to be achieved in the medium for a given output of the sound source. Further by the formation of standing waves the sound field is accurately defined.

The treatment of the liquid or melt can take place intermittently, only a part of the material being treated at a time in the separating chamber. Since it has been ascertained however that the procedure is within wide limits independent of the motion of the medium, it is proposed according to the invention to lead the material to be treated in an unbroken stream through the separating chamber.

For carrying out the process, frequencies of the lower ultra-sound range, that is up to 100 KH_z, which can be generated with suitable piezo quartz plates, with very great intensity, are particularly suitable as are also the frequencies of the limiting sound range between say 8 and 30 KH_z which can also be generated with very great intensity by electromagnetic or electrostrictive sound emitters.

In order however to achieve as effective as possible coagulation or flocculation, it is not unimportant what frequencies are used in any particular case. It has on the contrary been found practically that for each particle size a certain frequency range has the most efficient action. The following theoretical proofs also lead to this fact:

The vibration equation for particles in the vibrating medium is:—

$$m\frac{d^2x}{dt^2}=6\pi r\eta\left[A\omega\cos.\omega t-\frac{dx}{dt}\right]$$

that is the acting force $m\frac{d^2x}{dt^2}$ is equal to the known Stokes resistance force $6\pi r\eta\,\Delta v$ in which expression the velocity difference between particles and medium is $\Delta v = A\omega\cos.\omega t-\frac{dx}{dt}$

x being the displacement of the particle
m the mass of the particle
t the time
r the radius of the particle
η the coefficient of viscosity
A the amplitude of vibration of the surrounding medium
n the frequency of the vibrations
$\omega=2\pi n$ the pulsatance
σ the specific gravity

For the relation between the amplitude X_p of the particle and X_f of the liquid the following equation then applies:

$$\frac{X_p}{X_f}=\frac{1}{\sqrt{\left(\frac{4\pi\sigma r^2.n}{9\eta}\right)^2+1}}$$

If r is plotted as a function of n for the values 0.8 and 0.2 of the ratio $\frac{X_p}{X_f}$ the diagram shown in Figure 1 of the accompanying drawings is obtained, r being the abscissæ and n the ordinates. In the region A to the left of the curve $\frac{X_p}{X_f}=0.8$ all particles vibrate fairly uniformly with the liquid vibrations, while in the region C to the right of the curve $\frac{X_p}{X_f}=0.2$ they remain substantially at rest in relation to the liquid vibrations. In the intermediate region B however, as will immediately be seen, particles of different sizes vibrate with different amplitudes. Collisions between the particles are thereby caused, which in suspensions lead to flocculation.

According to the invention it is proposed therefore, in order to achieve maximum flocculation, in a range of particle sizes present between r_1 and r_2, to use frequencies between n_1 and n_2, the relationship of the range r_1 to r_2 to the range n_1 to n_2 being determined by the formula given.

The above described process can also be used in particular for acoustic de-mixing. With a suitable frequency it is found that in turbid liquids, the suspended particles according to the value of their specific gravity in relation to that of the carrier, move either to the vibration nodes or to the vibration loops, so that a separation between the turbid and clear liquid is thereby effected. At periodic intervals of $\frac{\lambda}{2}$ (λ=sound wave length) regions with increased turbidity are found, while at the regions between them the clarified liquid collects. The clear liquid so obtained can be separately drawn off or decanted off from the turbid liquid so that a separation and cleansing are achieved.

As an example of such cleansing, the clarifying of spinning liquids can be

given, which in all previous processes has presented considerable difficulties; in the same way, for example in oils, resinified particles or highly polymerised molecules can be separated from the other constituents.

The described process is further suitable for the removal of foreign admixtures from metallic or other melts, for changing the viscosity of oils, for increasing the coarseness of colloidal substances or for flocculating the suspended particles out of suspension. Finally any kind of disperse or non-homogeneous mixed liquid system that is to say systems in which one liquid is dispersed in fine particles in the other can in this way be demixed acoustically.

In many cases a single separating chamber which with reference to the economy of the process must not have too great a length (though its length must always be a multiple of its diameter), will not suffice to achieve complete clarification of the turbidity. According to the invention therefore several separating chambers are arranged in succession, in which a stepwise treatment of the liquid takes place. Here advantageously the intermediate product recovered in a succeeding stage is after settlement of the floccules again returned to the first stage for renewed treatment.

In some other cases the hydrosol as a whole does not tend to coagulation, so that flocculation by the sound influence does not take place with the desired speed. This case arises mostly when the concentration of the hydrosol is too low. According to the invention it is proposed therefore to add to the hydrosol to the treated, foreign, in particular chemically indifferent, suspensions, the particles of which then act as flocculation cores upon which the suspended particles to be separated settle under the action of the sound or ultrasound waves.

To carry out the process an apparatus is proposed which is characterised by a cylindrical container at one end of which is located the vibration delivering energy source as for example a magnetostrictive rod or a quartz plate, and which at the opposite end, to produce acoustic resonance is closed either by a fixed plate or by a movable piston, the liquid loaded with the hydrosol being led in at one end of the container and the treated liquid being led out at the other end.

Since the coagulation and separation of the hydrosol tends to take place at regular intervals along the tube, advantageously at these points the suspended particles flocculated at them are led off through separate outlet pipes together with a part of the liquid. In most cases this will be an intermediate product which has a medium concentration. The turbid liquid taken from the separating chamber, after sedimentation of the larger flocculated suspended particles, can be given a further treatment. Finally the uncleansed residue can again be returned to the first sound tube so that the liquid to be treated is connected in a closed circuit.

In further development of the invention on opposite sides of a magnetostrictive rod, a quartz plate or the like held in the middle and provided at the ends with piston members, separating chambers are arranged, in which the pistons work. By this measure both sides of the vibrating sound generator are utilised and the process thereby more economically carried out.

In the accompanying drawing, an example of embodiment of an apparatus for carrying out the process with simultaneous acoustic demixing, is illustrated in Figure 2. *a* is the tubular separating chamber to which the turbid liquid is led through the pipe connection *b*. At one end of the tube a magnetostrictive rod *c* is arranged, the piston end *d* of which entirely fills the cross section of the tube. This magnetostrictive rod is excited by a winding *e* through which flows a high frequency current, the piston *d* transmitting the vibrations to the liquid in the tube *a*. The sound waves generated are reflected at the opposite end of the tube by the longitudinally movable piston *f*, this piston being so adjusted that the chamber is in resonance with the sound vibrations. In the regions where the turbid liquid collects four outlets h_1, h_2, h_3, h_4 are arranged in the separating chamber at a spacing of $\frac{\lambda}{2}$ and in the regions between them in which the clarified liquid collects, four further outlets i_1, i_2, i_3, i_4; the distance from the first outlet h_1 to the last outlet i_4 is thus $\frac{3.5}{2}$ wave lengths. It will be observed that the first outlet h_1 is some distance, namely one full wave length from the face of piston *d* and that the total length of the chamber between the faces of pistons *d* and *f* is three wave lengths while the ratio of this length to the diameter of the chamber is about 4.8.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A process for the removal of solid and liquid suspended particles from melts and liquids containing them or the demixing

of such melts and liquids into turbid and clarified liquids in which the melt or liquid is excited into short wave vibrations by transmitting through an elongated body thereof, over the whole or substantially the whole of its cross section, sound waves of a frequency of about 8 to 100 KH_z, the wave form of which lies in or substantially in the longitudinal direction of the body of liquid, the length of the body being a multiple of its cross section so that any cavitation which may occur near the actual vibration generator does not hinder the coagulating effect of the vibrations.

2. A process according to claim 1 in which the separating chamber is tuned to resonance with the vibrations impressed on the medium.

3. A process according to claim 1 or 2 in which the medium to be treated is led in continuous stream through the separating chamber.

4. A process according to any preceding claim in which sound frequencies are used which are so related to the values of the radius of the particle sizes of the hydrosal treated that operations take place within the range between A and C substantially as described with reference to Figure 1 of the accompanying drawings.

5. A process according to any of claims 2—4 in which a demixing between turbid and clear liquid is effected in the sound tube, in that turbidity causing substances which collect at periodic intervals of $\frac{\lambda}{2}$ (λ=sound wave length) and clarified liquid which collects at the places between are separately removed.

6. A process according to any preceding claim in which the separation is effected stepwise, the recovered intermediate products being preferably returned in closed circuit to the preceding stages.

7. A process according to claim 6 characterised by the arrangement in succession of several separating chambers in which a stepwise treatment of the liquids takes place.

8. A process according to any preceding claim in which a foreign hydrosol is added to the medium to be treated.

9. Apparatus for carrying out the process according to any of claims 1—8, comprising an elongated cylindrical container at one end of which is located the vibration delivering energy source, as for example a magnetostrictive rod or a quartz plate, and which at the opposite end to produce acoustic resonance, is closed either by a fixed plate or by movable piston.

10. Apparatus according to claim 9 in which the liquid loaded with the hydrosol is led in one end of the container and the cleansed liquid led off at the other end.

11. A modification of the apparatus according to claim 9 in which at the places where increase of turbidity occurs and those where the clarified liquid collects, separate outlet pipes are provided for separate removal of these products.

12. Apparatus according to claim 9, 10 or 11 in which on opposite sides of a magnetostrictive rod, a quartz plate or the like held in the middle and provided at the ends with pistons separating chambers are arranged in which the respective pistons work.

Dated this 25th day of October, 1937.

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[This Drawing is a reproduction of the Original on a reduced scale.]

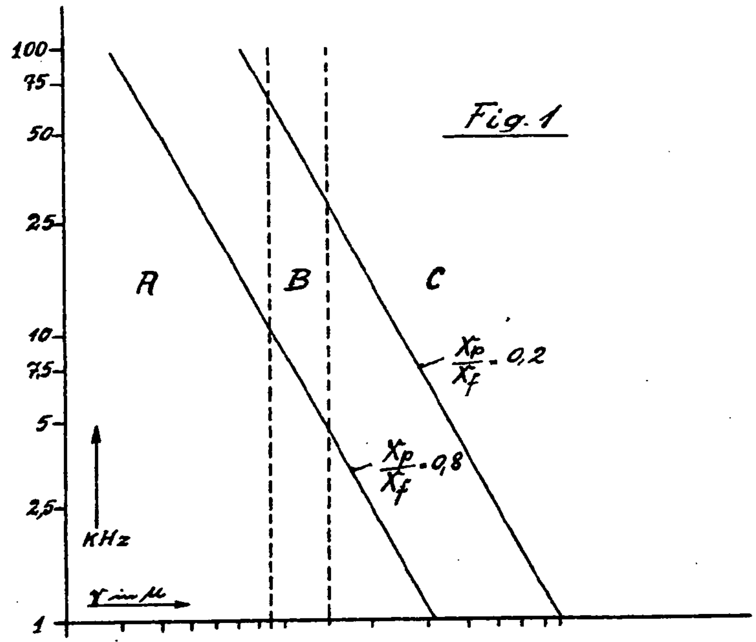
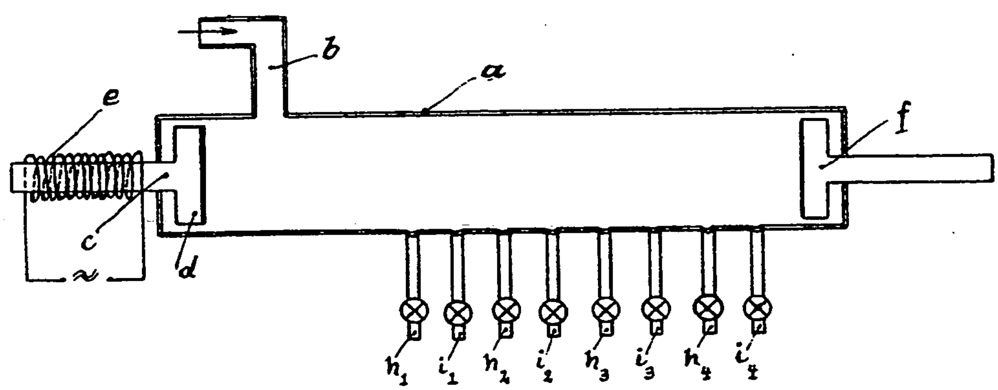


Fig. 1

Fig. 2



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